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U.H.F. offset generator for laboratory interference tests

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RESEARCH DEPARTMENT

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(EL-65)

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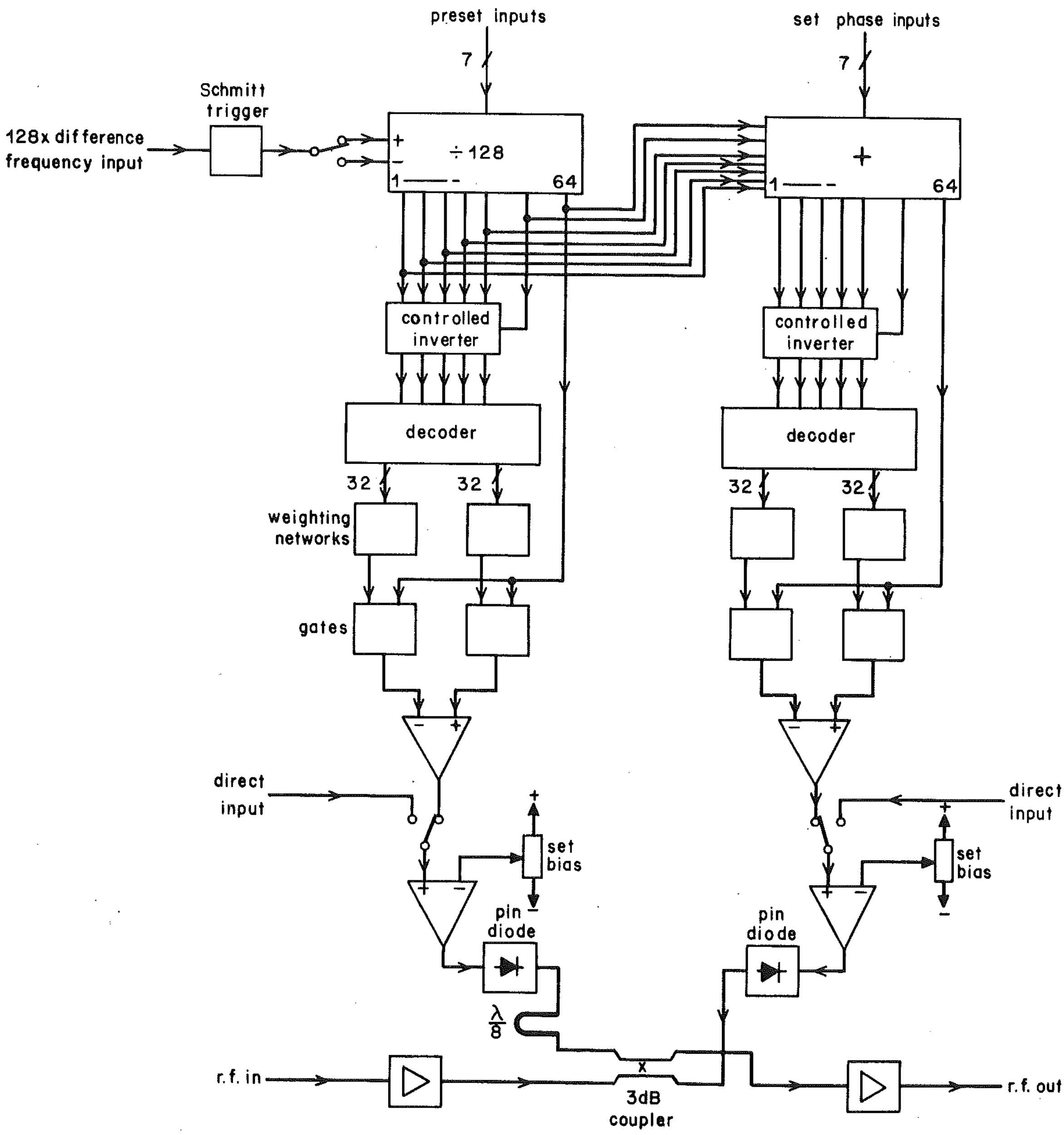

Fig. 1 - Block diagram

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U.H.F. OFFSET GENERATOR FOR LABORATORY INTERFERENCE TESTS

Summary

The equipment described in this report is designed to frequency shift a u.h.f. signal, modulated or unmodulated, by up to 50 kHz. The resulting signal can simulate a second transmission in the same frequency channel in laboratory studies of interference.

1. Introduction

When investigating television co-channel interference, it is necessary to have available two signals with a small and precisely known frequency difference. It must be possible to adjust and maintain this frequency difference to the required value with an accuracy of better than 1 Hz.

The method used up to the present time has been to use two independent signal sources adjusted as closely as possible to give the required carrier spacing. This method is generally impractical at u.h.f. when very stable frequency differences are required. The system described here operates at u.h.f. and produces the interfering signal by a single-sideband modulating technique in which two nominally quadrature signals at the wanted signal frequency are each modulated by one of two signals at the difference frequency. These latter signals are also approximately in quadrature, the exact phase relationship being dependent on the exact difference in phase between the r.f. signals (see Appendix).

Provided the amplitudes and phases of all components are accurately maintained and the system is free from non-linear distortion, the output is a frequency-shifted version of the input u.h.f. signal.

2. Description of circuit

2.1. Modulator

A block schematic of the equipment is shown in Fig. 1.

The r.f. input signal drive a 3 dB directional coupler via an amplifier with 12 dB gain. The two output arms of coupler are terminated by p.i.n. diodes. At u.h.f. the p.i.n. diode provides a linear resistive element whose resistance can be varied over a wide range by varying the direct current flowing through it.[1] In this application the value of this resistance is determined by the low frequency control voltage derived from the difference frequency drive amplifier. Thus the resistance of the p.i.n. diode and the degree of mis-match at the port of the directional coupler, will vary cyclically at the difference frequency. The lengths of the r.f. cables connecting the p.i.n. diodes to the directional coupler differ by one eighth of a wavelength at the mid-band frequency, therefore the two reflected waves produced by the mis-match of the diodes will be in quadrature. If the diodes are driven so as to give sinusoidal modulation of the two quadrature components of the input u.h.f. signal and if the two modulating waveforms are themselves in quadrature, the resultant in the fourth of the directional arm coupler will be a constant amplitude signal shifted in frequency by the modulation frequency. The direction of frequency shift is determined by which of the two modulation components is advanced by $\pi/2$ in phase.

A second amplifier r.f. fed by the fourth arm of the directional coupler supplies the r.f. output.

In order to minimise break-through of the input signal frequency to the output, it is necessary to adjust the standing bias current of the p.i.n. diodes in the absence of modulation to give as nearly as possible a perfect match to the directional coupler. This is achieved by providing the modulation drive amplifiers with individual adjustable bias supplies.

The modulation drive amplifiers may be driven from either external sources or an internal synthesised waveform.

Since the relationship between the drive voltage and the magnitude of the resulting reflected wave in the directional coupler is not linear, it is found that pure sine-wave drives do not give a constant amplitude output. By careful adjustment of the amplitudes and phases of the sinusoidal drive voltages this amplitude modulation can be made to be predominantly at the second harmonic of the modulation frequency with a level of 3% to 5%.

2.2. Waveform synthesiser

As an alternative to a pair of quadrature drives at the difference frequency, provision is made to accept a single input at 128 times this frequency. This input is used to drive a waveform synthesiser producing the required quadrature drives.

The input drives a seven bit binary divider (÷128). The first five stages of this divider are decoded to give 32 sequential pulse outputs. Resistors from these outputs give weighted currents to a common summing resistor, the

weighting being adjusted to give a voltage across this summing resistor in the form of the first quarter of a sine-wave. By repeating this cycle in the reverse order the second quarter of the sine-wave is generated. This reversal is obtained by using the output of the sixth stage of the divider to reverse the sense of the first five stages before they are applied to the decoder. A second set of similar weighting resistors is provided, driven from the same 32 decoded pulse outputs. This output is used to generate the second half of the sine-wave, the phase reversal being obtained by using the two drives to feed the inverting and non-inverting inputs of an operational amplifier. MOSFET switches driven by the seventh stage of the divider select alternately the two half-cycle drives thus giving the complete waveform. By adjusting the weighting networks the two halves of the waveform can be independently adjusted to give the optimum drive waveform, thus giving some degree of cancellation of the amplitude modulation produced by the non-linearity of the p.i.n. diode modulator referred to in Section 2.1.

The divider outputs also supply a seven bit binary adder. The outputs from this adder are treated in exactly the same way as the previously described output from the divider and will thus produce the second (quadrature) drive waveform. The second set of inputs to the adder are derived from a binary coded switch that can be set manually to adjust the phase difference between the two components of the modulation waveform. Although this is normally set for a $\pi/2$ phase difference, some departure from this value may be required to compensate for deviations from the nominal quadrature phasing of the u.h.f. signal inputs (see Appendix). These deviations arise from imperfections in the directional coupler and from the fact that the difference in the line lengths of the two diode cables is only exactly $\lambda/8$ at the mid-band frequency. By reversing the direction of count the sign of the frequency shift can be changed.

Provision has also been made to permit external digital drives to be used to preset the divider to any required count, thus giving facilities for changing the r.f. phase in discrete steps according to a pre-determined programme. This method of operation has been proposed as a possible alternative to offset frequencies and may require investigation at some future date.

3. Performance

As has been stated in Section 2.1, when direct sine-wave drives are used the minimum level of residual amplitude modulation that can be achieved is about 3% to 5%. When the synthesised drives are used it is possible, provided the modulation frequency is below about 1 kHz, to obtain a slightly better performance in respect of amplitude modulation. However, the residual modulation then consists mainly of breakthrough of the transient edges of pulse waveforms which produce very noticeable impairments of a television picture. This modulation becomes worse as the difference frequency is increased.

The p.i.n. diode modulators are temperature sensitive and, although partially compensated, their drift prevents an input carrier suppression of more than 40 dB being maintained for an extended period.

These deficiencies are not significant when the instrument is being used to shift a television signal for use as an interfering source in subjective tests of interference effects.

If the instrument is used to shift the frequency of an unmodulated carrier, the unwanted amplitude modulation of the output can be removed by a simple amplitude limiter. The resulting carrier can then be modulated to produce a television signal of considerably higher quality than is obtained by frequency shifting the modulated signal.

The use of an unmodulated carrier is in any event necessary when different programmes are required on the two signals.

4. Conclusions

A u.h.f. offset generator has been produced that can transpose a complete u.h.f. television signal by up to 50 kHz, the resulting signal is adequate for use as an interfering signal for interference tests.

5. Reference

1. A feasibility study of an adaptive receiving system for u.h.f. television. BBC Research Department Report No. 1971/32.

6. Appendix

If a r.f. input signal to the device has the spectrum

$$a_1 \sin \omega_1 t + a_2 \sin \omega_2 t + a_3 \sin \omega_3 t$$

and it is required to shift this frequency by pt, let the phases of the two r.f. input signals be θ and $\pi/2 - \theta$ then the phases of the two difference frequency signals should be $-\theta$ and $\pi/2 + \theta$, i.e. if the relative phase of the r.f. signals is $\pi/2 - 2\theta$, the relative phase of the modulating signals should be $\pi/2 + 2\theta$.

The output of the device is then

$$(a_1 \sin(\omega_1 t + \theta) + a_2 \sin(\omega_2 t + \theta) + a_3 \sin(\omega_3 t + \theta))$$

$$\sin(pt - \theta) + (a_1 \sin(\omega_1 t + \pi/2 - \theta) + a_2 \sin(\omega t + \pi/2 - \theta) +$$

$$+ a_3 \sin(\omega_3 t + \pi/2 - \theta)) \sin(pt + \pi/2 + \theta)$$

$$= \cos 2\theta \, (a_1 \cos(\omega_1 t - pt) + a_2 \cos(\omega_2 t - pt) +$$

$$+ a_3 \cos(\omega_3 t - pt))$$

this is at the difference frequency.

Or alternatively,

$$(a_1 \sin(\omega_1 t + \theta) + a_2 \sin(\omega_2 t + \theta) + a_3 \sin(\omega_3 t + \theta))$$

$$\sin(pt + \pi/2 + \theta) + (a_1 \sin(\omega t + \pi/2 - \theta)$$

$$+ a_2 \sin(\omega_2 t + \pi/2 - \theta) + a_3 \sin(\omega_3 t + \pi/2 - \theta)) \sin(pt - \theta)$$

$$= \cos 2\theta \, (a_1 \sin(\omega_1 t + pt) + a_2 \sin(\omega_2 t + pt) +$$

$$+ a_3 \sin(\omega_3 t + pt)$$

this is at the sum frequency.

The factor $\cos 2\theta$ is a constant dependent on the phase error between the r.f. input signals. It is a maximum when $\theta = 0$ i.e. the signals are in quadrature. If $\theta = \pi/4$ or $3\pi/4$ the output goes to zero, this is when the inputs are either in phase or in antiphase.

The chief source of phase error in the r.f. input signals is the eighth-wavelength line. If the device is required to operate over the whole u.h.f. television band, 470 MHz to 960 MHz, and the line is adequate to be correct at the arithmetic mid-band frequency, the phase error at the band edges will be approximately 30° with a resulting amplitude reduction of 1·3 dB. Imperfections in the directional coupler and its terminations may increase the total error slightly but the change of amplitude across any one television channel will be negligible.

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